EXHIBIT 4

In re Flint Water Cases,
No. 16-cv-1044

Rebuttal Report of Dr. Larry L. Russell

Veolia

March 3, 2023

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This report addresses reports by the Veolia experts. Each expert report is addressed in a separate section. This report includes by reference my previous reports from 2020, 2021, and 2022 on this matter. Generally, where those reports have already addressed the materials covered in the Veolia expert reports, they are not repeated here.

- Expert Declaration of Dr. William Bellamy, February 3, 2023
- Expert Report of Dr. David Crowe, February 3, 2023
- Declaration of Dr. David Duquette, January 6, 2021
- Declaration of Dr. Graham Gagnon, January 6 2021
- Supplemental Report of Dr. Graham Gagnon, February 3, 2023
- Expert Report of Stephen A. Hubbs, February 2, 2023
- Expert Report of Dr. David E. Kimbrough, February 3, 2023
- Expert Report of Sheldon V. Masters, Ph.D., February 3, 2023
- Declaration of Siddhartha Roy, February 2, 2023

3 Expert Report of Dr. David Crowe, February 3, 2023

3.1 Summary of Response

Dr. Crowe's report does not change my opinions.

Dr. Crowe appears to think that if only we could go back in time and get the ideal data set from the Flint Water Crisis collected during early 2014 to late 2015, then he might be able to prove his suppositions. Data from the real world is rarely perfect, but there is a great weight of data that supports the opinions I offer in this litigation. Dr. Crowe also seems to think that form is more important than function, when he criticizes our metallurgical laboratory for not having a sign, rather than concentrating on the data we collected.

Additionally, Dr. Crowe ignores my assessment of the Copper Development Association (CDA) 50-year warranty, wherein I calculated that the average rate of uniform corrosion was the nominal wall thickness of the pipe divided by 50. Anyone familiar with the CDA warranty would know that non-uniform events and corrosive water are excluded from qualifying for the CDA warranty, meaning that only uniform corrosion is covered. There is no other way to evaluate the CDA warranty, in my opinion, with these explicit exclusions.

As I will explain more thoroughly, four through wall pits in a single home represent a failed piping system (whether the leaks are leaking water or not – they did leak water and the pipe wall is fully penetrated/compromised). The steel pipe in [redacted] has survived well during the majority of its life when the DWSD water was distributed, and it deteriorated substantially more rapidly during the periods when the Flint River water was utilized. Dr. Crowe criticizes Dr. Edwards' utilization of steel nails as corrosion coupons. However, the steel utilized in nails is high quality and nails are manufactured under ASTM F1667, which specifies the steel quality and strength. Dr. Edwards works provide a useful comparison of the DWSD and the Flint River water relative corrosion rates, indicating that the Flint River water corroded the steel in the nails at a rate of approximately nine times that of the corrosion inhibited DWSD water.

The data collected from the homes in Flint speak for themselves.

3.2 Review of Dr. Crowe's Report Summary

Dr. Crowe's report begins with a section titled Summary. That section is repeated here in its entirety for discussion with responses following each section. It is unclear if these numbered paragraphs represent Dr. Crowe's opinions as he does not define them as such. Further, he fails to present his basis for each opinion, complicating what would should otherwise be a straightforward evaluation of his opinions and basis in his expert report.

1. Because there was no available documentation of the locations in the homes where the samples were removed, we could not confirm their exact location in the homes. Chain-of-custody from the homes to the possession of Dr. Russell was not provided, leaving uncertainty whether we have seen all of the piping removed. There was no documentation from the labs that performed measurements or the analysis, so we could not confirm whether they were certified or the equipment was properly maintained and calibrated.

Such basic procedural deficiencies indicate a lack of familiarity with corrosion engineering and basic scientific procedure.

Dr. Crowe reviewed all of these pipes *insitu* in his terms for both homes. He could have reviewed his memory, notes, and/or photos which would have easily shown him where each of these pipe samples were harvested from both homes. The location or orientation of the pipes would not have changed my opinion in any way, and is not required to evaluate the condition of these pipes.

Also notable is that Dr. Crowe was scheduled to review three homes, but reported that he had Covid symptoms after doing the first two homes. Dr. Crowe's confession about potentially contracting and/or spreading Covid during his earlier site inspections validates my decision to delay my trip to Flint as it was too unsafe to travel and enter resident's home at the time that he did so. As I've previously stated, I did not travel to Flint until February 2022 because of my concerns over Covid and the health of both myself and the residents.

Dr. Crowe's criticisms regarding the chain of custody are also simply off base. I was present for, and directed, the removal of all pipes. There is no separate chain of custody documentation that would be expected for work performed under this scenario. Dr. Crowe was provided with access to all pipe samples that were removed from the two homes during my work there in 2022.

As will be discussed later in this analysis, the Dr. Crowe's criticisms of the laboratory and testing procedures are wrong. The analyses were performed by an experienced metallurgist using proper equipment and techniques. Dr. Crowe demonstrates his inexperience in domestic pipe corrosion investigations with these comments.

2. Storage of the samples was unacceptable, with no sealing of the ends of the tubes, and some evidence of storage in damp conditions which caused rusting and contamination of cut surfaces. In his deposition, Dr. Russell testified that he kept the box of pipe samples in his garage since February 2022, with some samples in individual bags and some not, which is not proper storage. Thus, contamination and degradation of the samples are very real concerns. Again, these deficiencies indicate a lack of familiarity with corrosion engineering and basic scientific procedure.

Contrary to the observation made by Dr. Crowe in December 2022, our work was completed shortly after I returned from Flint. At that time, there was no corrosion observed on the cut end of the pipes, nor would it have impacted my assessment or opinions if it had been there. The samples were stored to be used as exemplars for trial and were stored adequately to protect them from the elements between sample collection and testing. Dr. Crowe provides no actual evidence of contamination, nor observations supporting that there is potential contamination between pipe samples. There is no contamination between samples, and the storage of samples has not altered their condition in a meaningful manner. Further, I have directly overseen the removal, storage, and laboratory analysis of thousands of domestic water pipes and fixtures throughout my career, involving litigation matters on over 500,000 homes. Dr. Crowe's statements about lack of familiarity with corrosion engineering lack basis or common sense. Dr. Crowe provides no written protocols or standards for either the extraction or storage of pipe samples.

3. The problems with handling, principally resulting in the potential for contamination, mechanical damage, and scale degradation, mean that the results of analyses already performed by Dr. Russell are questionable.

Contamination and degradation of the pipes following removal from the homes was not an issue. These pipes were removed, protected (cushioned) and stored for transport. The samples were tested shortly after my return to California. Dr. Crowe provides no credible explanation, or proof of any contamination or degradation. The pipes were protected and stored in a new clean plastic tote. The laboratory testing was performed as soon as possible following removal, and was performed under my personal supervision. The samples were never released from my personal control from the time of collection through delivery to our metallurgical laboratory. These samples were maintained in my personal possession until they were transferred to my associate, Dr. Todd Russell's, possession the day before Dr. Crowe was provided access to these pipe samples, as indicated on the chain of custodies which he was provided.

Regarding testing instrumentation, Dr. Crowe should have invested in a proper precision metallurgical point micrometer (we utilized a Mitutoyo micrometer calibrated with precision gauge blocks for all testing) to make it possible to accurately determine pipe wall thickness. The instrument used by Dr. Crowe, as shown in Figure 6, is a Home Depot or Harbor Freight quality tool, which is neither of proper quality or design to make the assessments that Dr. Crowe has presented. Had Dr. Crowe made the request during the inspection, which was performed at the metallurgical laboratory, we would have been happy to provide him with the proper tools to measure the wall thickness of the pipes. However, neither Dr. Crowe nor anyone from his team requested samples for conducting their own analyses.

Copper Pipes

4. The copper pipes samples from the homes were typical of residential copper piping, with no visual evidence of mechanical damage or deformation, corrosion pitting, or loss of thickness.

The techniques utilized by Dr. Crowe to determine wall thickness were inadequate. Dr. Crowe should have utilized a point micrometer and to measure at several locations along the pipe, as we did. The device that he shows in the picture in his report is simply not suitable for making accurate wall thickness determinations (especially in the orientation shown on his photo as there is a burr on the cut end of the pipe that produces an artificial ridge making the pipe wall to appear to be thicker than it actually is). Accordingly, unless he is relying on the measured data in my report, he does not have firm basis or support for making these assessments.

5. The copper pipe specimens did not show any significant wall loss. Though limited by the poor quality of sample preparation by Dr. Russell, our caliper measurements found the copper pipes were actually thicker than he claimed. There were no indications of the exact sites where Dr. Russell measured pipe wall thickness, again pointing to a failure to follow basic scientific procedures. In any case, most of Russell's measurements are within the range of tolerance per the specification for new copper piping and therefore do not support any claim of wall loss.

Dr. Crowe provides no explanation for how he performed his caliper measurements, and I stand by my pipe wall thickness measurements, which were performed with the proper instrumentation. The range of tolerance is put into the ASTM B 88 standard to accommodate manufacturing variations; however, based on the review of thousands of feet of pipe including hands on measurements of copper pipe manufactured domestically and abroad, and that copper pipe is uniformly manufactured to the minimum wall thickness allowed by B 88 to save the manufacturer money.

6. Surprisingly, no metallurgical cross-sectioning was done to confirm pipe wall thickness. Dr. Russell claims that the pipes were damaged, which was not evident, but cross-sectioning is basic procedure in any corrosion engineering failure analysis. There was ample pipe sample length to conduct cross-sectioning, but no explanation has been offered why cross-sectioning was not done.

Cross sectioning was unnecessary based on the work I performed and the observations I made, as presented in my report. Dr. Crowe does not explain how cross-sectioning would have changed his analysis and tellingly he did not request to do any cross-sectioning to try to refute any of the observations or opinions in my report.

7. Samples of the internal pipe surface were not cleaned to remove scale for visual or microscopic examination. There is no visual evidence of the inside surface of the piping, and only a thin oxide is visible. Thus, there is no evidence to support claims of corrosion damage. Some corrosion product from residual flux at joints is visible, apparently undisturbed since installation.

My transport and preservation of the samples were sufficient to preserve the residual flux and the scale that covered it, contrary to Dr. Crowe's criticism of my techniques.

It is unclear from Dr. Crowe's statement what he meant regarding the inside of the pipe. He states that there is no visual evidence of the inside surface of the piping, yet Dr. Crowe was permitted to observe the various lengths of copper pipe that had been sectioned for inspection.

8. Dr. Russell's scraping of the inside surface to remove loose scale was done haphazardly and in a superficial manner that did not sample the full thickness of the oxide. It is likely that the sampled copper pipe wall scale is not representative, especially where the composition varies through the thickness of the scale.

I sampled a representative amount of the steel pipe scale that was in contact with the water. That scale was located near the surface that was in the direct contact with the water and most critical for my analyses. Dr. Crowe did not request any pipe samples to perform his own investigation using his techniques. He further provides no technical references or procedures upon which his criticisms are based, only a loose definition of his own personal preference for methods on corrosion engineering and testing.

Galvanized Steel Pipes

9. The condition of the galvanized pipe samples was typical of residential galvanized piping after many years of service. Some corrosion at screwed joints, weep spots where pits have penetrated through the wall, and significant internal scaling are what we would expect anywhere, especially after decades of use. The galvanized pipe samples are evidence of long life at Flint, and are in very good condition considering their age, estimated at 84 years at the [redacted] *home. The galvanized pipe long ago exceeded its expected service life of 40-60 years (7).*

While Dr. Crowe provides no basis for this section, it should be noted that his references are not up to professional standards. As just one example, his reference (7) regarding the expected life span of galvanized pipe is a webpage from a home inspection company located in Florida. There is no indication of the source or the validity of the information presented to support his observation of the life expectancy of galvanized pipe. The longevity of the pipe is the result of characteristics of the water sourced from DWSD that reduced the rate of corrosion of these pipes in the middle of their life cycle. He provides no information to back up his supposition that the pipes are 84 years old.

I disagree with Dr. Crowe's evaluation that the galvanized pipers were in "good condition." As detailed both in his inspection photos, and in my testing and analyses, these pipes contained multiple through-wall pits and—as Dr. Crowe himself points out—"weep spots where pits have penetrated through the wall," which are known to the lay person as a leak. A pipe with any leak, be it active or temporally plugged by minerals is not a pipe in "good condition."

10. Samples contained heavy scale, typical of decades-long exposure and not consistent with the scale removal and damage claimed by the plaintiffs to have happened during the use of Flint River water from April 2014 to October 2015.

The level of scale is common for steel pipe exposed to corrosive waters. The high levels of metals, and much of the color in the water observed in locations across Flint during the FWC originated from the dissolving pipe scales of this nature. Dr. Crowe provided neither a logical explanation of where the elevated concentrations of metals originated from nor any meaningful explanation of the source of these metals.

11. There is no visual evidence to support Dr. Russell's claim of wall thinning – only isolated localized pin-hole pits which resulted in 'weepers.' These are typical of galvanized steel pipe after several decades of service, and there is no way to tell when the 'weepers' formed. Failure at threaded joints during disassembly was due to the thinned wall at the roots of threads cut in the pipe, and corrosion on the exterior where the protective galvanizing had been removed during thread cutting.

Dr. Crowe is incorrect in his assumptions. Of course, thinning occurs at the threaded sections, but the dissolution (corrosion) of the pipe occurs due to the effect of the corrosiveness of the water on the threaded joint. Notably, he does not refute (nor can he) the fact that the lack of an orthophosphate corrosion inhibitor could have significantly contributed to the thinning. The impacts of corrosion were thus particularly impactful during the period when the pipes were unprotected due to the lack of an orthophosphate corrosion inhibitor during the Flint Water Crisis.

12. There was no indication that the samples had been sectioned to do metallurgical cross-sections. This is good practice for failure analysis of pipes and tubes to measure thickness. The thickness of cut samples appeared to be very good, with no evidence of significant attack. Certainly, the samples did not show "paper thin" or otherwise severely compromised walls. Evidence of compromise would have been visible macroscopically at pipe wall cuts, and it was plainly not present in the samples presented.

Again, it was not necessary to measure the wall thickness of a pipe that had been severed. Zero wall thickness is zero wall thickness. Dr. Crowe did not request any portions of these pipes to perform any testing, and has no credible data to support his position that the pipes are in "very good" condition. It is unclear to me how Dr. Crowe can look at a section of pipe with the telltale signs of leak on the exterior (evaporated minerals from the water) and claim that the wall thickness is "very good."

13. Sample areas of internal surface had not been cleaned to allow proper examination of whether damage has occurred. There was no cross-sectioning at pinhole pits to characterize the extent of attack or its causes.

Nothing would have been gained by section through the pit and no useful information would have been gathered from doing so. If there was additional useful information to be gained by so doing, I would have done it.

14. Lead in the scale measured by Dr. Russell likely is from the original galvanizing layer. The weight percentage amounts of lead measured by ICAPS were about 1/100th of the weight percentage of lead that would have been present in the original galvanizing layer, so would be expected to be present.

Dr. Crowe's opinion is purely speculative and incorrect. If Dr. Crowe was aware of why galvanization is done and its role, he would know that the most likely fate of the interior zinc coating was to sacrifice itself in the first three years or so to avoid red water until the corrosion of the steel pipe was addressed by proper water treatment. There is no zinc coating remaining on the interior of the pipe and the lead content of the prior zinc coating is a red herring at best. This comment is neither correct nor useful, nor it supported by any testing that Dr. Crowe has performed (as he has performed no testing of the interior scale).

15. There was no scale cross-sectioning for analysis of layers by Dr. Russell, which could have aided in determining the age of the scale. There was no indication where the scale sample was taken for analysis, and it may not be representative.

Dr. Crowe did not request a pipe sample to perform this type of analysis despite being able to request one. Apparently, he was satisfied by the results we presented, or he would have wanted to expend more effort on his own work on these samples.

16. Analysis of the scale in tubercles on steel pipe is essential to determine the cause of that corrosion. Copper deposition from upstream copper piping or fittings onto the surface of steel piping can initiate localized corrosion by a galvanic action (5), which leads to the formation of tubercles, but the presence of copper in the tubercles was not investigated. Such copper deposition occurs independent of water quality and would be expected in any plumbing system with copper upstream of galvanized pipe.

Dr. Crowe personally inspected both houses prior to sample collection, and as documented in the CPI inspection reports, he observed and documented the plumbing configurations present in both houses. My experience is that copper deposition onto downstream steel pipe has everything to do with water quality and that when this condition is experienced there are far more than four pits in the downstream steel pipe. Dr. Crowe's comment is neither correct nor useful—as Dr. Crowe does not identify what mechanism he things caused the copper to dissolve and then establish on the steel. He ignores the real reasons for the through wall pits: water quality that supports pitting.

17. There is no indication of when during the life of the pipes corrosion occurred. The quantity of scale points to the likelihood that it was undisturbed during the period of 2014-15. Based on my inspection, there is no reason to conclude that there was acceleration of corrosion during 2014-15.

Dr. Crowe has provided no support for his positions about when corrosion occurred, and merely speculates. Based on his reference list, Dr. Crowe has not reviewed most of the critical information about the water quality and corrosion that occurred during the FWC, and importantly, he does not refute the fact that the lack of an orthophosphate corrosion inhibitor could have contributed significantly to the corrosion seen in the pipes. To that end, he hasn't even reviewed the reports of the other Veolia experts on the subject, let alone depositions, complaints about water quality issues in Flint during the FWC, or lead and copper testing performed during the FWC, etc. Dr. Crowe cannot make any credible assessment of what occurred to these systems during the FWC without reviewing the relevant information. As one of the many examples, he ignores the work done by the Edwards team on the rate of corrosion of steel in the treated Flint water.

3.3 Response to Russell Supplemental Report (2022) Opinions

Dr. Crowe presented a response to opinions S2 through S11 in my 2022 Supplemental Expert Report. Each of the following sections addresses Dr. Crowe's responses presents my opinion, relevant quotations of Dr. Crowe's commentary, and response. Dr. Crowe does not successfully rebut any of my opinions, and his commentary and unsupported positions do not change my opinions.

3.3.1 Opinion S-2

Dr. Russell Opinion S-2: "*As demonstrated in this report, essentially all of the homes in Flint (37,000) were built before 1985 when high lead solder was still in use and the homes with copper pipes have substantial amounts of leaded solder and are connected to high lead valves and faucets throughout Flint. Over 60 percent of Flint homes were built before 1945 when lead service laterals were still in common use.*" (4)

Dr. Russell claimed that high lead solder is present in copper piping, but found none in either of the homes from which he sampled copper piping. Nor did he show any damage to lead-containing valves or faucets.

Dr. Russell notes in Section 3 of his supplemental report that the majority of homes in Flint were built prior to 1960 before copper pipes were widely used. He provides no information on when galvanized piping, installed widely before 1960, was replaced. For piping installed after 1935, for example, replacements would likely have been made from the mid-1980's onward (based on the expected lifespan of galvanized steel pipe). Lead-free solder was used after 1986, so most replacement copper piping would have lead-free solder, and this was found in both of the homes where samples were taken.

Furthermore, Dr. Russell claims that 60% of homes were built before 1945 and would have had lead service lines, but his Table 3.4 indicates that a survey in 2017 found only 7.32% of service lines were lead.

(Crowe 2023, p. 29)

Of course, I found no lead in the solder of the homes where the pipe samples were taken. They were all partially replumbed after the leaded solder ban in 1986. To have used leaded solder after that date would have been a crime perpetrated on the residents by their hired plumbers My references were to the houses that had copper systems as a replumbing option installed before 1986.

The fact that 60 percent of the homes were built before 1945 is a fact that Dr. Crowe could have confirmed for himself. At the time my of 2020 report, I was forced to estimate the number of lead service laterals, and we did so. I have been involved in the issue of lead service laterals for over 20 years, and in the beginning of my involvement, the American Water Works Association (AWWA), one of the largest trade associations for the water purveyors, estimated that there were essentially no lead service lateral connections in the United States. The AWWA now estimates that there are over 3 million lead connections in the United States. Dr. Crowe should be aware that the FAST program has indicated that over 16 percent of the homes had lead service lines, mostly located in the center of the older part of Flint.

3.3.2 Opinion S-3

Dr. Russell Opinion S-3 *"By focusing on two homes of named plaintiffs, namely [redacted], the defendants artificially narrowed the useful data collected during their field work. To be consistent with the defense focus, I chose to remove pipe sections from those same houses to avoid adding even more variables into the data being collected. Reviewing the pipes from two homes provides infinitely more information/ data than was collected during the defense review of these homes, as the interior of the pipes can be observed and analytical measured."* (4)

In the fall of 2020 I inspected the plumbing at [redacted] [sic] and [redacted] because these were two of the three homes offered for inspection by the plaintiffs. I was unable to inspect the third home offered because I developed Covid-19 or flu symptoms the day after inspecting the first two homes. According to my understanding, the plaintiffs' legal team refused to reschedule. Thus, the plaintiffs' lawyers narrowed the access to homes, not the defendants.

Dr. Russell's inspection of the inside of the pipes several years after the water source was switched back to DWSD has limited value because after several years we cannot know what characteristics of the condition of the pipes date from before, during, or after 2014-2015. Scales and corrosion products will have reformed and deterioration likely occurred between 2016 and now, and this damage or change cannot be distinguished from older changes.

(Crowe 2023, p. 30)

Regardless of why Dr. Crowe reported on only two homes, it was deemed prudent to me to collect pipe samples from the homes in which he had already photo cataloged the piping. To improve the database of information about these two homes, I made a site visit to Flint in February 2022 during which I collected the piping. Having this data is informative, and we now have a lot more data than existed before my site visit in February 2022. The scale in the pipes is similar to ice core samples which reveal the secrets of the past. Like ice cores, the remaining pipe scales integrated the past corrosion and water quality conditions into the deposit remaining in the pipe. All of that said, there is a great deal more information available to support my opinion, beyond these particular pipes, that the conduct of Veolia both caused and prolonged corrosive and contaminated water conditions in Flint, and those conditions were capable of harming Flint residents, which is further established in in my 2020 expert report.

3.3.3 Opinion S-4

Dr. Russell Opinion S-4 *"The Detroit Water and Sewage Department's ortho phosphate addition corrosion treatment regime was (and is) very effective at minimizing corrosion of copper pipes in Flint. The effective corrosion rate of the DWSD water in the copper pipes observed was substantially less than the 0.0005 inches (0.5 mils) per year utilized by the Copper Development Association (CDA) in their 50 year warranty for copper pipe."* (4)

The Copper Development Association may have indicated an expected life for copper pipe of 50 years, but this does not imply that the corrosion rate would be 0.5 mpy. Dr. Russell seems to have arrived at this conclusion by dividing the thickness of a tube wall (0.028-inch) by 50 to obtain a loss rate of 0.5 mpy so that the wall thickness would be lost in 50 years. In fact it would fail before it thinned to nothing.

Furthermore, the actual corrosion rate would be much lower. Our inspection of the tubes taken from the subject homes shows they have suffered no demonstrable loss. This includes the time of exposure to Flint River water, which evidently caused no damage. This suggests that orthophosphate has very little influence on corrosion of copper piping.

The thickness measurements made by Dr. Russell on the copper pipe samples could not be duplicated; we measured higher thicknesses. At any rate, the thicknesses measured in Table 5.1.1 were within the tolerance for manufacture of new tube, so there was no evidence of loss. Indeed, Dr. Russell acknowledged in his deposition that new copper pipe is often manufactured at the lower end of the specification range. I also found the same 0.026-inch thicknesses measured by Dr. Russell in new copper pipe from a hardware store. Visually, the inside surface looked smooth and covered with a thin oxide layer.

(Crowe 2023, pp. 30-31)

As discussed earlier, Dr. Crowe did not utilize appropriate equipment to measure the pipe wall thickness, nor did he collect measurements at appropriate locations away from the cut surface. Accordingly, any assessment based on his measurements are meaningless.

Dr. Crowe's conclusion that orthophosphate has very little influence on corrosion of copper piping is false. The answer for why the copper pipes look the way they do is obvious and it is because of the protective nature of the scale formed by the addition of orthophosphate by DWSD during the entire life of these pipes except during the FWC when the pipe wall thinning most likely occurred. The logical conclusion is that this thinning occurred during the period of time when there was no orthophosphate addition and there was increased corrosion, namely the time between early 2014 and late 2015 when the corrosive Flint River water was being distributed to the homes and businesses of Flint.

My opinion is completely logical: very little corrosion occurred during the period of time (since 1994) that DWSD added orthophosphate (the entire life of this copper pipe sampled at the two homes until the Flint Water Crisis when no orthophosphate was added).

3.3.4 Opinion S-5

Dr. Russell Opinion S-5 "The copper pipes at [redacted] were reportedly installed in 2008 during a plumbing remodel and as such they were assembled without leaded solder. These pipes were however impacted by the corrosive water served during the Flint Water Crisis losing approximately 0.002 inches of their wall thickness." (4)

The assertion that the copper pipes at [redacted] lost 0.002-in. thickness is based on erroneous assumptions and errors in calculation of corrosion rates. That calculation requires an initial thickness and a final thickness. The loss is the difference in these two values. But Dr. Russell does not know the thickness at the beginning of 2014-2015, so he assumes it was the original wall thickness of new pipe; in doing this he ignores the loss in thickness of the wall between its installation and the beginning of 2014-2015, and any possibility of wall thickness below nominal due to normal manufacturing variations. He also does not know the thickness at the end of 2014-2015, so he uses the current thickness, ignoring loss of thickness that could have occurred between the end of 2014-2015 and now.

In any case, there is no visual evidence of corrosion to support the claim of thinning. Dr. Russell just assumes that damage occurred during 2014-2015, a belief that has no factual basis. And Dr. Russell's claim that the copper pies [sic] at [redacted] lost 0.002-in. thickness is entirely unfounded. Dr. Russell's wall thickness measurements are within the tolerance for new Type M copper pipe. The wall thickness measurements taken by Dr. Russell are entirely consistent with new copper pipe.

With no evidence of corrosion, the precise year in which the copper pipe was installed does not matter because any calculated corrosion rate is practically zero. However, in his deposition, Dr. Russell agreed that the homeowner indicated that the copper pipes were installed in [redacted] in 2000, not 2008 as Dr. Russell claimed in his report. Dr. Russell testified in his deposition that the installation of the copper pipes in 2000, not 2008, makes his opinions stronger. I disagree. To the extent the copper pipes experienced any loss of wall thickness (and there was no evidence of that), the installation of the pipes in 2000 rather than 2008 means that they are eight years older than Dr. Russell assumed and provides an additional eight years when any loss of wall thickness could have occurred for reasons entirely unrelated to the water switch in 2014-15.

(Crowe 2023, pp. 31-32)

Dr. Crowe refuses to admit the obvious: orthophosphate addition by DWSD was extremely effective at reducing corrosion in the Flint home's piping. He conveniently ignores that any wall thinning would likely occur when there is no orthophosphate addition, i.e., during the Flint Water Crisis.

3.3.5 Opinion S-6

Dr. Russell Opinion S-6 "The steel pipes at [redacted] were impacted severely during the exposure to the corrosive water during the Flint Water Crisis. These pipes experienced through wall pitting and were down to paper thin remaining wall thickness in many locations at the time that I removed them. (4)

The steel pipes at [redacted] were decades old, and were, and are long past their expected life. Weeping at oxide-filled pits in galvanized line is expected, especially in piping estimated to be 84 years old. This is not evidence of a severe event, which would likely have opened up all the weepers. There is also no way to tell whether any through-wall pitting occurred before, during, or after 2014-15.

Due to exposure for several years after the Flint water event, the pipes tell us nothing about what may have occurred during the event. Looking at the samples, it is evident that the surfaces are well covered with iron oxide and mineral scale which protects the underlying steel from exposure to water. These corrosion products are typical in steel and cast iron lines, and they build up over time, eventually plugging the line in some service locations. There is no way to tell whether these oxides were disturbed during the Flint water event. Their thickness suggests that the scale has never been disturbed enough to wash it away. Visual inspection shows the pipe wall to be very thick in all of the cross-sections. Dr. Russell's claim that severe corrosion occurred during the Flint water event is entirely unsupported.

(Crowe 2023, p. 32)

Dr. Crowe misses the point again. There is obviously water conductivity from the water column to the pipe wall through the scale. It is not water that one is concerned with, but it is the transfer of oxygen that is critical in corrosion rate determination. While Dr. Crowe dwells on novel words like "weepers," he is missing the point, which is that these pits advanced until they were through the wall. There is no more advancing for the pit to do as there is no more wall left to advance through – there is a hole.

Mr. Michael Schock testified that from his experience with lead containing scales in steel and lead pipes, that it was his opinion, that these scales began to dissolve immediately upon exposure to the corrosive Flint River water. His opinion is borne in part out by observations of colored water being reported immediately after the switch occurred. The colored water clearly showied that the Flint River water was corroding and attacking the internal pipe scales within the pipes of the Flint distribution system immediately.

3.3.6 Opinion S-7

Dr. Russell Opinion S-7 "Exposure to the corrosive water distributed during the Flint Water Crisis substantially compromised the life span of the steel pipes in Flint. Just as the steel pipe service laterals were removed by the City and replaced with copper, the steel pipes within these homes require replacement to halt exposure to the lead containing scale accumulated over many years from their lead service laterals. The Flint Water Crisis made these lead scales more readily exposed due to the aggressive Flint River water attack on these scales. Replacement is required to provide the residents with a plumbing life span required to service these homes in the future without catastrophic leakage and failure in the future." (4)

Dr. Russell stated in his opinion that the "water distributed during the Flint Water Crisis substantially compromised the life span of the steel pipes in Flint" and that they could fail or leak catastrophically. The pipe samples from [redacted] are likely 84 years old, as discussed in the section "Sample G" in

this report, so the expected life span has long ago passed, and still the pipe was in service with only a few weep spots until Dr. Russell removed the pipes in 2022. Considering the thick walls seen in the cross-sections, the pipe likely could have continued in service for many more years. I am also unaware of any reports of widespread failures of galvanized steel pipes in Flint during and after 2014-15.

Dr. Russell claims that the Flint water event exposed lead corrosion products in the scale, creating an on-going risk to residents. Visual examination of cross-sectioned tubes shows heavy scale inside the lines, contrary to any assertion that the Flint River water exposed lead-containing material. In addition, analysis of the scale by ICAPS reported by Dr. Russell in his supplemental report found 0.00418 weight percent of lead (41.8 ppm), a tiny fraction of the amount in the original zinc coating, which was likely 'Prime Western' zinc containing up to 1.4 weight percent lead as discussed in this report under "Sample C', p.14. This trace amount of lead could have been introduced due to uncapped pipe ends during shipping, or by the saw during sectioning.

As discussed above, the galvanized steel pipe samples taken from [redacted] *are typical of residential galvanized piping after many years of service and do not show any sign of accelerated corrosion related to the water switch in 2014-15. Even if the pipe samples from* [redacted] *showed damage, however, it is speculative to extrapolate from pipe samples* ***in a single home*** *that all galvanized steel pipe throughout an entire city need replacement.*

(Crowe 2023, pp. 32-33)

Dr. Crowe's statements suggest that he is unfamiliar with the purpose of galvanizing on steel water pipes. Following World War II during the institution of the Marshall Plan, rebuilding the infrastructure of mainland Germany required the installation of thousands of miles of pipe. Undoubtedly, many of the German homes had been plumbed in lead (as they were in Paris). The United States could not reinstall lead pipes in the late 1940's, and the use of galvanized pipes was called for as the best material of choice. That was due to the fact that galvanization stops the formation of red water due to iron corrosion initially. Galvanization stops that corrosion by sacrificing itself by dissolving into the water phase (often called white rust or zinc oxide). The concept is that by the time the interior zinc coating is dissolved, the water treatment program will provide water that is stabilized from a corrosion standpoint and reduce the formation of red water. Thus, it is extremely likely that there is no interior galvanized coating present in these pipes, and that whatever lead may or may not have been deposited in the zinc coating on these pipes was long gone many years ago.

It is more likely that pipes from [redacted] are exemplars for the pipes from other homes in Flint than is Dr. Crowe's premise that these pipes are somehow outliers statistically different from the other homes. The data collected supports my conclusions.

3.3.7 Opinion S-8

Dr. Russell Opinion S-8 "Based on the work of Dr. Marc Edwards in 2015, the steel pipes in Flint were rapidly aged by the distributed Flint River water. The treated Flint River water was more than 8.5 times more corrosive than the DWSD water resulting in the pipes experiencing over 11 years of additional corrosion damage in the 16 months during the Flint Water Crisis. The resulting damage is a direct analogy to the 'straw that broke the camel's back' rendering the homes to require full pipe replacement." (4)

Dr. Russell claims that the life of piping has been shortened significantly based on the testing result published by Dr. Marc Edwards for corrosion of nails in water from a home with uncommonly poor quality water. Dr. Edwards' nail study is not representative because the presence of scale and corrosion deposits on the surface of galvanized steel pipes, as would be present in home plumbing, would have resulted in much lower corrosion rates.

The demonstration of corrosion of bare, abraded nails in Flint River water by Dr. Edwards in 2015 did not represent what would happen in real piping that has been in service for years. The principal difference is that oxide scale build-up over many years provides protection to the galvanized steel piping. The testing of corrosion protection strategies performed in the EPA test rig uses sections of line with typical scale intact on the inside surface, carefully mounted into a flow loop, with water flowing through it. This is how corrosion testing for water systems should be performed to obtain meaningful results.

Other differences between the nail test and real pipe are that the surface of the nails was cleaned, but real pipe would have been left with its oxide surface to provide protection. Nails are typically a poorer grade of steel with inclusions and other impurities which would serve as initiation sites for corrosion, and would tend to accelerate corrosion rates. Nails are also heavily cold worked, and this would increase the corrosion rate significantly, exaggerating differences in side-by-side comparisons.

If the exposure to Flint River water had been as severe as claimed by Dr. Russell, numerous failures of piping would have been reported, as piping nearing the end of its life was pushed over the limit. These reports would have increased in number as the water event continued. To my knowledge, there were no reports in the press or otherwise that indicate this, and no repairs have been reported (or are even evident) in the subject homes.

Dr. Crowe's "weepers" are pipe failures. As is often said, "the tire is only flat on the bottom", but once subjected to non-uniform corrosion pipe failure is defined by when the pipe wall is penetrated. The plumbing at [redacted] had at least 4 through wall pits. This plumbing had failed and was only functional by a happenstance involving sealing due to leaking and the formation of evaporate on the outside of the pipe where the pit penetrated the wall. The one house that Dr. Crowe originally inspected with galvanized plumbing, and that I performed further investigation on, was evaluated for failed steel piping evidence, and there were four pipe failures identified. Again, the piping collected only included that present in the basement level that was accessible. There are substantial amounts of pipe segments present within the walls, and those are likely to contain additional pits based on the observations of the pipe segments in the basement. Once again, the answer is obvious, this house needs to be replumbed. We replumbed the basement during our pipe sampling taking (but only for the piping that was accessible in the basement and not the piping behind the walls of the house).

Dr. Crowe criticizes Dr. Edwards' utilization of steel nails as corrosion coupons. However, the steel utilized in nails is high quality and the nails are manufactured under ASTM F1667, which specifies the

steel quality and strength. Dr. Edwards' work provides a useful comparison of the DWSD and the Flint River water relative corrosion rates, indicating that the Flint River water corroded the steel in the nails at a rate of approximately nine times that of the corrosion inhibited DWSD water.

Full house pipe replacement is the only solution for resetting the clock on the damaged pipes in Flint homes and businesses.

As documented in the short list of references that Dr. Crowe relied upon, he did not attempt to seek out any resources related to pipe failures in the community. There is documentation of high frequency of water main breaks throughout Flint following the change to the Flint River water. While this home was not re-piped during the FWC, it clearly has pipe failures in multiple locations. Given the severity of the FWC, it is not surprising that during the FWC the media focus was on the immediate problems of colored water, metals (lead) concentrations, and water main breaks. The lack of media reporting on the condition of the pipes in Flint is irrelevant.

3.3.8 Opinion S-10

Dr. Russell Opinion S-10 "The copper pipes at [redacted] were impacted by the corrosive water served during the Flint Water Crisis losing approximately 0.006 inches of the wall thickness of the pipe most likely during the period when orthophosphate was not added. (4)

Dr. Russell's assertion that corrosion of the copper piping at [redacted] occurred during the Flint water event has no factual basis. The original thickness of the copper pipes are unknown, so we cannot calculate any loss in thickness. The measurement of a loss of 0.006-inches for Sample E could not be confirmed, and could be an error or a measurement taken from a bend in the pipe, which is naturally thinner. Visually, there is no evidence of corrosion.

(Crowe 2023, pp. 34-35)

As Dr. Crowe is well aware, the ASTM standard for copper pipe is B88 (promulgated in 1932) and the manufacturers rely on that standard to produce uniform product quality having a wall thickness of 0.28 inches, nominally. This pipe was sold in the United States under ASTM B88 and it is perfectly logical to utilize the 0.28-inch wall thickness as the starting thickness for calculating the loss of wall thickness.

3.3.9 Opinion S-11

Dr. Russell Opinion S-11 "The lead levels remaining in the heavily corroded and tuberculated steel pipe sections collected from [redacted] *(and most likely at all other similarly plumbed homes having water service laterals made from lead) are excessive and present a risk that can only be addressed by complete re-plumbing due to the severity of the corrosion damage, pitting of these pipes, and the high levels of lead remaining in the pipe scale. Due to their age, and as was demonstrated by the defense data collection with an XRF, the brass faucets and valves in these homes have high lead content which exceed the current standards for lead content by up to two orders of magnitude and likewise require removal and updating with fixtures that meet the current less than 0.25 percent lead requirement." (4)*

Dr. Russell claims that lead levels in the scale remaining in [redacted] *piping (and elsewhere) are excessive and risky. The reported values of 41.8, 168 and 83.3 ppm are dry content, and should really be reported as mg/kg rather than ppm. They represent weight percentages of 0.00418, 0.0168, and 0.00833 weight percent, all of which are tiny percentages of the amount of lead that would have been present in the original galvanizing layer, as discussed above. Furthermore, the method of saw-cutting to cross-section the tubes (and expose the scale for sampling) could have introduced traces of lead from the exterior galvanizing layer on the pipes, and that could be what was measured.*

The galvanized steel pipes at [redacted] *are long past their expected life, and could be replaced to prevent failure and improve their reliability, but this has nothing to do with water quality during the 18 months of Flint River use in 2014 and 2015, just their advanced age.*

(Crowe 2023, p. 35)

The unit of mg/kg is equivalent to parts per million (ppm), and the reason for measuring the lead in the scale by wet chemistry was to achieve a lower detection level than can be achieved with either EDX or XRF (detection limit for these instruments is approximately 1,000 ppm or 0.1 percent by weight). The measured lead concentrations are tiny weight percentages of the weight of the scale, but the EPA Action Level for lead of 0.015 ppm is even tinier. These levels of lead are what would be expected for steel pipe downstream of a lead service lateral. It is absurd to postulate that the cutting of a wet water containing pipe would deposit traces of lead into the interior scale during pipe cutting. This is again pure speculation by Dr. Crowe.

I agree that it is time for this steel plumbing to be replaced, but the question is what pushed the pipe over the edge. Indeed, it was the exposure to the corrosive water during the Flint Water Crisis which could and should have been addressed by the input of Veolia as water quality experts to guide the City of Flint, as Veolia promised in their proposal submittal. Generally, cold water galvanized pipe has a better appearance (less corrosion) than do the pipes from [redacted] The aggressive water quality from the FWC is reasonably certain to be the cause of the pipe interior condition.